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U.S. ARMY
DARCOM

U.S. ARMY RESEARCH OFFICE

PROGRAM GUIDE

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CONTENTS

INTRODUCTION 1

SCIENTIFIC PROGRAMS

Biology 3

Chemistry 7

Electronics and Computer Science 10

Engineering Sciences 13

Geosciences 19

Mathematics 26

Metallurgy and Materials 29

Physics 34

INTRODUCTION

This brochure describes some research areas of interest to the Army. It replaces the ARO Program Guide issued in October 1976, and the Supplement issued in July 1977.

The ARO program is organized by scientific discipline, and the reader will note some overlap between sections. Also, it should be kept in mind that the program is not limited to the topics listed, and proposals in other areas containing innovative scientific ideas and novel engineering concepts will be considered.

The basic and applied research areas described may have short- or long-range impact on Army capabilities. If progress in certain research areas requires the interaction of several investigators, and especially if an interdisciplinary approach is necessary, the Army Research Office will consider proposals for comprehensive research programs at an annual level between $150k and $450k. However, only a small number of such large programs can be initiated in Fiscal Year 1980.

Proposals may be submitted at any time. Prior to the submission of a formal proposal, especially for larger comprehensive programs, we strongly encourage informal discussion and submission of a brief outline of the proposed research. Key ARO staff members and their areas of responsibility are listed below.

Dr. Francis W. Morthland (Biology)
Dr. Robert G. Ghirardelli (Chemistry)
Dr. Jimmie R. Suttle (Electronics)
Mr. James J. Murray (Engineering Sciences)
Dr. Leo Alpert (Geosciences)
Dr. Jagdish Chandra (Mathematics)
Dr. George Mayer (Metallurgy and Materials)
Dr. Robert J. Lontz (Physics)

Inquiries related to comprehensive and interdisciplinary programs should be addressed to the Technical Director, ARO. For information concerning the format of proposals, evaluation procedures, reporting requirements, etc., please request a copy of the ARO brochure, "Research Contracts." The ARO telephone number is (919) 549-0641. The mail address is: U. S. Army Research Office, P. O. Box 12211, Research Triangle Park, NC 27709.

H. Robl

HERMANN ROBL
Technical Director

BIOLOGY

I. Introduction

Extramural research in the life sciences is supported by the U. S. Army Research Office, the U. S. Army Medical Research and Development Command, and the U. S. Army Research Institute for the Behavioral Sciences. These programs are coordinated in the research proposal review process and by frequent contact and information exchange by staff members. A short description and addresses of the other agencies are found at the end of this chapter.

II. Program of the U. S. Army Research Office

Interactions of the biological world with the physical are all-pervading and especially critical for military operations. They alter skilled task performance, affect the integrity of mechanical and electronic systems, alter man-machine cooperative efficiencies, increase logistic burdens due to spoilage of rations, and increase the need for resupply of repair and replacement parts.

The ARO extramural program is currently oriented to the thrust areas described below. Descriptive material shows some of the critical topics. Obviously, the lists are not exhaustive, nor can all of the topics be supported simultaneously. Rather the thrust areas and topics are intended as stimuli to your thinking. If you desire to pursue this discussion further, or if you have research ideas that you wish to bring to our attention, please contact either Dr. F. W. Morthland (Biochemistry) or Dr. Shirley R. Tove (Microbiology) by letter or telephone (919) 549-0641. You may wish to submit a short, informal write-up of your ideas (1-2 pages) for a determination of Army interest and desirability of submitting a formal proposal.

The major thrust areas are:

1. Food and Ration Research

The modern Army cannot live off the land by individual or small groups foraging as in the distant past. The Army has need of new knowledge to help solve its rationing problems. These problems group themselves into: new ways of preparing, preserving and delivering food to the soldier; means of assuring wholesomeness; new methods for detecting spoilage, loss of nutritional factors; ways of measuring and assuring acceptance by the troops; protection of stored items from insect and animal pests.

2. Protection of Materiel from Biodegradation

Many microorganisms, bacterial and fungal, attack the materials from which Army materiel is fabricated. This attack, frequently upon mundane ubiquitous items in the supply systems, e.g., sandbags and electronic connectors, contributes to both gradual and catastrophic failure of military equipment. Its contribution to the logistic problems of resupply and maintenance is large. Research is needed on properties of materials that make them susceptible or resistant to biological attack. The problems of commensal growth systems and the effect of the juxtapositions of several possible substrates on organism growth should be explored to better understand the field problem.

3. Environmental Quality, Protection, Rehabilitation

Concern from the civilian sector for the effects of military activities on natural ecologies will increasingly restrict training and operational activities during peacetime. Attempts to adjust or redesign equipment to eliminate detrimental effects will be excessively costly if done without a thorough understanding of these effects. Studies must cover effects on individual living species, e.g., toxicology of effluents from Army units, equipment and manufacturing waste products, and the effects of interacting groups of species in large ecological systems.

A major problem area is to balance protection of materiel for its useable lifetime with the need for rapid dissolution when it has become waste. Studies are needed on built-in means to destroy this waste by biodegradation or physical disintegration. The use of enzyme or other biological systems to achieve conversions of large scale wastes and by-products of military manufacture to useful products will be explored. Examples of major military disposal problems are food system wastes and the particular problem of aromatic nitro compounds from explosives manufacture.

4. Defense Against Chemical and Biological Weapons

The continued threat of chemical weapons requires basic knowledge on modes of action in target organ systems of potential agents. A number of agents act at the nerve synapse to impede neural transmission. Research on these systems will help in finding improved means for prophylaxis or treatment of these agents' effects. Some areas for study are: basic physiology studies on affected tissues; transport across skin barriers; development of non-animal systems for screening studies and toxicology research. There is a need for rapid analytical procedures to detect and identify potential agents in field environments. Finally, new approaches to decontamination of large areas without destruction of materiel in the process will be explored.

Over the next few years we will emphasize support for studies on nerve transmitters. The central nervous systems of higher animals are activated and controlled by transmitter molecules acting at synaptic junctions. These control basic function and behavior in the animal. More knowledge is needed on function and control of transmitters other than acetylcholine. Adequate prophylaxis and therapy for intoxication by such agents will depend on an understanding of modes of action of transmitters. Of particular interest are those systems involved in control of behavior since their alteration may frequently result in functional incapacitation without being life threatening. Research in this field might include study of transmitter synthesis, release, synaptic receptor interaction, reset mechanism and transmitter blockage.

A most difficult problem facing the Army is the need for some way to detect pathogenic organisms in the environment in a timely manner so as to avert a major loss of military effort due to infectious disease used as a weapons system. New developments in biosciences instrumentation offer increases in speed and enhanced levels of sensitivity. Coupling of these instruments to computer-manipulated pattern recognition techniques may provide the opportunity for orders of magnitude improvement in speed of detection and identification. In addition to detection and identification, rapid and non-destructive techniques for decontamination of materiel are needed.

5. Sensory Factors in Performance Enhancement

The soldier in the modern military complex must be highly skilled in observing and interpreting input clues from his operating environment. Input is usually by visual and aural systems. The functional physiology and activity of these sensory systems to provide meaningful information is under continuing study. This provides a foundation for improved design of man-machine systems. An intriguing concept is the possibility of simultaneous input of data in man by two or more sensor systems.

The non-human animal world holds a strong lead over man in ability to detect traces of chemicals in the environment. This lead may be a thousand- or a millionfold in sensitivity. It is a frustrating fact that despite the clever efforts of many investigators, the exact mode of such biosensory detection sensitivity is still a mystery. A continuing small effort will be supported in the hope that we too can learn how to detect and identify indicator chemicals and their sources in extremely low concentrations. Biosensory means also show promise for more sophisticated control of pests that infest and damage stored materiel and subsistence items by use of species-specific chemical signals.

6. Other topics will be seriously considered on their scientific merit, Army program relevance and originality. A small number of symposia, conferences and workshops will be supported in part or whole to provide interchange of ideas of value to ongoing programs of our laboratories.

III. U. S. Army Medical Research and Development Command Program

For those proposals related to purely medical topics, the investigator is invited to contact the Commander, U. S. Army Medical Research and Development Command, Ft. Detrick, Frederick, MD 21701. The Army Medical Department research program divides into four major areas:

1. Care of the Wounded. Shock and trauma, blood transfusion therapy, burn therapy, dental research (includes repair of maxilofacial injury), new medical materiel, medical field equipment systems.

2. Prevention and Control of Infectious Diseases. Communicable disease, immunology, preventive measures against vectors and reservoirs, tropical medicine, internal medicine (dermatology, hepatitis, enteric diseases), nutrition, veterinary research.

3. Enhancement of Performance. Biomedical stress research, psychophysiology, physical performance and man-machine interface problems.

4. Protection of Man Against Environmental Hazards. Environmental hygiene and engineering, aviation medicine, radiobiology (ionizing and non-ionizing radiation, laser effects), environmental medicine - adaptation to extreme terrestrial environments, toxicology of military materials and effluents of military activities.

IV. U. S. Army Research Institute for the Behavioral and Social Sciences Program

Research in behavioral sciences, social sciences, and training techniques for the Army is administered by the U. S. Army Research Institute for the Behavioral Sciences. Related inquiries or proposals should be addressed to the U. S. Army Research Institute for Behavioral and Social Sciences, ATTN: PERI-T, 5001 Eisenhower Avenue, Alexandria, VA 22333.

CHEMISTRY

Chemical phenomena and considerations pervade modern life in general and Army operations in particular. As the science of molecules, chemistry is involved whenever materials are produced, converted to energy or otherwise destroyed. It interfaces with many other disciplines, a situation reflected in the fact that a significant portion of the current chemistry program comprises contracts funded jointly with other divisions at ARO.

There exist a number of practical Army needs and desires, the fulfillment of which will likely or necessarily be based on molecular considerations, i.e., on advances in the field of chemistry. Each of the following descriptions of an Army need or interest is followed by a list of topics likely to have some bearing (with varying degrees of immediacy) on the problem. It is intended to be representative but not exhaustive.

Rapid detection and identification of explosives and chemical agents.

Electro-analytical techniques for sensing, detection and identification of trace components; fluorescence probes, laser induced fluorescence; mass spectroscopic techniques, including chemical and field ionization, and those requiring a minimum of sample preparation; photoacoustic spectroscopy; techniques especially applicable to organophosphorus and nitro compounds.

Quiet, efficient power sources with low thermal emission.

Processes occurring at electrodes; chemically modified electrodes; new electrolytes, solid and liquid; electrocatalysis; new electrode materials, diaphragms; factors influencing dendrite formation, mechanism of passivation; ion transport, ionophores.

New, more effective energetic materials and higher efficiencies in the production of energetic materials.

Exploratory synthesis and characterization of nitro compounds, nitrogen-fluorine compounds, other fluorine-containing oxidizers; energetic plasticizers and elastomeric binders; boranes and alkylcarboranes.

Unconventional approaches to nitration; oxidation by nitric acid; chemistry of the symmetric perhydrotriazine and perhydrotetrazocine systems.

Deeper understanding of the chemistry underlying the effectiveness and responsiveness of propellants and explosives.

Kinetics and mechanism of fast, highly exothermic reactions; new spectroscopic techniques to characterize and monitor same; nonequilibrium systems; ignition, initiation, activation and deactivation and meta-stable molecules; solid state unimolecular and intermolecular reactions; factors governing transition to detonation stage; combustion in high pressure regimes; efforts to examine representative model compounds, devise theoretical models.

Rapid, thorough means to destroy chemical agents, other contaminants.

Catalysis due to micellar structure, in microemulsions, at fiber or thin film interfaces, in oriented media; enzyme models; techniques enhancing nucleophile reactivity, especially toward pentacovalent phosphorus; photooxidation, electrooxidation.

Better obscurants.

Chemistry of smokes, aerosols, foams; factors affecting stability of colloids; nucleation, dispersion, interaction of particles; absorption and scattering of electromagnetic radiation; thermal efflorescence.

Direct chemical means to produce coherent radiation.

Fluid oxidizers, nitrogen oxides, nitrogen-fluorine compounds; luminescence; metal vapor, metal powder oxidation; appropriate energy level determinations.

NOTE: See also the Metallurgy and Materials section for work closely related to the following two areas.

Prevention of metal surface erosion under combined thermal, mechanical and chemical stress.

Reactions occurring at hot gas-solid interfaces; reactions at microcrystalline interstices; techniques to monitor surface changes: low energy electron diffraction, photoelectron spectroscopy, inelastic electron tunneling spectroscopy, electron energy loss spectroscopy.

New materials and ways to tailor properties of existing materials.

Exploratory synthetic efforts: electrically conducting polymers, materials for service in stressful environments; molecular structure/property relationships for materials.

Greater protection for the individual soldier.

New fibers and fabrics affording protection against weather, flame, chemical agents; absorption, scatter and reflection of electromagnetic radiation; dyes matching natural background; mechanism of chemical inhibition of hydrocarbon ignition; mechanism of flame retardation; char formation; efflorescence, intumescence.

Better fundamental insight into phenomena of known or potential practical utility.

Triboluminescence, chemiluminescence, piezoelectricity, pyroelectricity.

Several of the topics outlined above (either in terms of the ultimate Army objectives or the scientific subareas) could very suitably be addressed by coherent, multi-faceted efforts involving two or more senior investigators. Discussions with ARO staff prior to the formulation of a formal proposal would be especially advisable in such cases.

The chemists at ARO welcome the opportunity to discuss research activities in order to determine where the interests of investigators and the Army may intersect. The list below is intended to assist the reader in choosing the most appropriate person at ARO to contact. All of us, however, stand ready to answer questions regarding relevance to the Army mission, or technical matters of a general nature, or to assist in the direction of an inquiry.

Dr. Robert G. Ghirardelli - Stereochemistry, structural chemistry, catalysis in solution or suspension.

Dr. David R. Squire - Surface chemistry, kinetics of fast reactions, physical polymer chemistry.

Dr. Bernard F. Spielvogel - Inorganic chemistry, analytical chemistry, electrochemistry.

Dr. G. Ronald Husk - Organic chemistry, metal-organic chemistry, synthetic polymer chemistry.

ELECTRONICS

I. Introduction

This task contributes to the electronics and communications science and technology base through exploration of novel phenomena and generation of new concepts. The objective is to solve critical Army problems related to exploratory development where progress has been inhibited by a lack of understanding of fundamentals or a scarcity of basic data. Research to obtain fundamental information is performed in the areas of signal generation, transmission, reception and processing; computer systems and sciences and communication theory; and solid state electronics including semiconductors, superconductors, magnetics and dielectrics, circuitry and networks. Work under this task has application to a wide variety of exploratory efforts contributing to the solution of such technology-related problems as communications, command and control, surveillance, target acquisition and night observation, intelligence and electronic warfare.

Outlined below are six subtasks of current emphasis. Due to the changing nature of technology, research has to be derived from flexible research objectives. Therefore, the presented objectives are general rather than specific in order to be responsive to unexpected, novel ideas which will impact on the Army technology base. A brief or preliminary proposal prior to submission of a complete proposal is encouraged. If additional information is required concerning areas of interest, potential investigators may contact the individuals responsible for the areas of research interest listed below.

II Physical Electronics

The Army needs to understand those parameters of electronic materials which potentially affect or determine device performance. Research in this area will contribute to the basic knowledge and characterization of electronic, magnetic, and optical materials. Areas such as generation, transport and control of charge carriers in semiconductors, magnetic phenomena and electronics contributing to novel fiber optics systems are of interest. This long-range research contributes to the technology base of future electronic devices of relevance to the entire scope of Army electronics needs.

Specifically, some of the research fields of current interest are: electronic and structural properties of binary, ternary and quaternary semiconductors; semiconductor surface and interface studies; high-field and nonequilibrium transport phenomena in semiconductors; transport physics in ultrasmall dimensions; properties of carriers in confined structures; magnetic effects above 20 GHz; and interfaces between optical fibers and optical devices. Contact: Dr. Horst R. Wittmann.

III. Electron Devices

We are interested in the exploration of new or improved operating principles of devices in order to greatly improve performance and reliability while decreasing initial manufacturing set-up and continuing production costs. Studies of the fundamental limitations of the operating ranges of devices will provide directions for potential improvements. Included in this short to medium range research effort is the evaluation of existing device barrier problems in the fields of generation, detection and processing of electronic signals. Consistent with the general trend, research in semiconductor devices is emphasized to increase the power-frequency product or the bandwidth of electronic devices. We are also interested in novel, fundamental research leading to improved microwave power tubes, such as TWT, CFA and magnetron tubes. Some examples of current interest are: transit time effects on semiconductor devices; millimeter and submillimeter wave devices including ferrites; the physics of photo-resists for submicron fabrication; acoustic oscillators of exceedingly high long-time frequency stability; and highly efficient electron emitters for cathodes. Contact: Dr. Horst R. Wittmann.

IV. Antennas and Electromagnetic Detection

The Army has a critical requirement to use electromagnetic waves most efficiently under given operational constraints in order to optimize mission objectives. Navigation, radar, electronic warfare, communication, direction finding and electronic countermeasure depend on full understanding and efficient use of antennas, atmospheric/ground propagation, and sensitive, optimized detection schemes. The objective of this program is to expand the basic knowledge of electromagnetic radiation, propagation and detection in areas which will impact on Army technology. Included in our interests are studies of the propagation and launching of waves in waveguides for the millimeter to optical spectrum. Examples of current emphasis are: electrically small and conformal antennas including the fundamental bandwidth limitations and efficiency trade-offs; effects of proximity to complex structures; new approaches leading to low-cost, high-performance millimeter- and submillimeter-wave antennas; mode control in optical fiber systems and techniques to interface integrated optic and fiber optic systems; and radar resolution enhancement and target detection/classification in a clutter environment. Contact: Dr. James Mink.

V. Circuits, Networks, and Related Systems

In the process of acquiring specialized defense systems, limited production of custom integrated circuits is often required. In order to minimize cost and time of such acquisition, it is desirable to have the capability to design, test, and simulate integrated circuits prior to fabrication. The use of computers for design, production, and testing of the very large scale IC's of the future is essential. A special need exists for research in high-frequency and optical circuits. This research will contribute to improved performance, reliability, availability, and cost savings for all Army electronic systems. In support of these needs, research will be supported in the areas of integrated circuit design, testing, and simulation including computer-aided layout and design; integration of existing and new devices on common chips; and optical and high-frequency circuit theory and design. Contact: Dr. William A. Sander.

VI. Signal Processing, Communications, and Related Systems

These systems are essential to fast, accurate, reliable, and efficient transmission of information which may be in speech, RF, image, radar, or other form. Research is supported to produce improved system performance. Reduced size, weight, and cost of electronic equipment should also result. Need for research has been identified in the theory of multi-dimensional digital signal processing; signal processing and communication for multi-signal, interference, and jamming environments; adaptive, optimal, and nonlinear signal processing; and image processing. This research is relevant to digital communications, electronic warfare, target detection and identification, and guidance and control. Contact: Dr. William A. Sander.

VII. Computers and Information Processing

1. Architecture. The modern Army, which depends for many of its operations on reliable and efficient computer systems, maintains a continuing interest in achieving more efficient and reliable computer and communication equipment, organizations, and procedures. Computer architectures for efficient distributed processing, controls to improve memory-access techniques, and reliable digital transmission are expected to contribute materially to this Army area of interest. Examples are direct communications between machines (as in sensors to display consoles), data base computers, and data networks.

2. Software. The high cost of software magnifies the importance to the Army of methods for software cost reduction, for increasing the reliability of software for more efficient software production, and for decreasing software maintenance costs. Improved methods for distributed and parallel processing are important. New approaches are needed in languages and procedures for improved software quality and in program testing and verification. Increased use of microprocessors demands simplified operating systems, simplified application-software production methods, and more flexible display software. Contact: Dr. Jimmie R. Suttle.

ENGINEERING SCIENCES

I. Introduction

Research supported by the Engineering Sciences Division is concerned with solid mechanics, fluid mechanics and power generation. Research supported in the discipline of solid mechanics includes structural mechanics and dynamics; fatigue and fracture mechanics; friction, lubrication and wear; vibrations, theory of machines and noise; response of materials and structures to impulsive loads; wave propagation; kinematics; mechanics of composite materials; elasticity; viscoelasticity and plasticity. The fluid mechanics research program embraces such sub-fields as wind tunnel testing techniques, boundary layer studies, turbulence, separated flow fields, dynamic stall, aerodynamics, and fluidics. Research in the area of power generation typically includes investigations in propulsion, combustion, chemical laser cavity flows, engine concepts and cycles, and fuel conservation. The details of the scope and thrust areas in each of these disciplinary areas are included in the following narrative.

II. Solid Mechanics (Dr. Edward A. Saibel, Dr. Frederick W. Schmiedeshoff)

Solid mechanics deals with the response of solids to static and dynamic loads, thermal gradients and various types of interaction between solid materials. It is also concerned with the development of optimal structural design techniques. An understanding of the behavior of solids under static and dynamic conditions is important for the design and analysis of helicopters, weapons, vehicles, and other Army materiel.

The sub-categories of solid mechanics are discussed below.

1. Mechanics of Solids: The determination of constitutive relations, analysis of states of stress and strain, and development of experimental methods of examining materials, are basic in analysis and design of structures to withstand fracture, fatigue, excessive deformation or wear.

Research in mechanics of solids permits an understanding of the internal stress and strain distribution of bodies when subjected to various types of loadings. These results allow optimum structural design as well as establishing the physical properties of materials required for the structure. Work is needed in elastic-plastic 3-dimensional analysis under static and high strain rates of loading.

2. Structural Mechanics and Dynamics: Methods of analysis and design of structures which will support or withstand static and/or dynamic loads are required. For this purpose, properties of materials and values of pertinent material parameters must be determined. Included in this sub-category are projects on stress, strain and motion analysis of structures with a goal of developing better, lighter, reliable and safe Army structures.

A wide variety of structures are used by the Army. A transport vehicle for any liquid imposes on the designer the problem of a shell-type design exposed to shock and vibration. An aircraft structure for operation in the field presents new problems of providing light-weight structure that gives crew protection as well as ease of maintenance and permits maximum aircraft performance. A gun barrel is an example of a thick-wall cylindrical structure, loaded suddenly by very high internal pressure and heat shock. The cylindrical, conical, or ogive shell of a missile is typical of thin shell design.

3. Fatigue and Fracture Mechanics: Theories of fatigue and fracture are required; criteria for failure are needed.

The field of analytical mechanics is still in a primitive stage due to the extreme simplification and rudimentary assumptions upon which analytical investigations are based. Increased emphasis on more realistic modeling of fatigue and fracture mechanics, both theoretically and experimentally, is necessary to predict more accurately the behavior of Army materiel.

4. Shock, Vibration, Wave Propagation and Noise: The effects of external forces of a deterministic or random nature, including shock loads on materials and structures, are of great interest, as well as the vibration of structural components and the noise resulting therefrom.

Army materiel is subject to shock and vibration. The firing of a gun is a common example. The vibratory response of bridges is widely recognized. Vibratory failure of aircraft has plagued the design engineer. The nature of vibration is partially understood but is still a problem in all velocity regimes of aircraft and missiles. The effect of impact, explosion, and resulting stress wave propagation on structures and materials of Army importance are included in this study.

The problem of acoustical excitation deserves considerable attention from the viewpoint of the structural effects produced. Such excitation may induce failures even in substantial structural elements, to say nothing of components such as electronic tubes. The ability to predict near-field sound levels of different types of rocket or turbo-power plants by analytical methods has not been developed to a significant degree and design qualifications depend upon actual field tests.

5. Surface Mechanics: This topic comprises lubrication, friction and wear, all of which are basic to many applications of interest to the Army. A few applications of obvious importance are in vehicle design, construction and maintenance, gun mechanisms, gun tube surfaces, and helicopter gears.

6. Composites: Particular attention is being paid to composites as a means of optimizing material properties such as strength-to-weight

ratios and dispersion of undesirable waves in structures such as those due to impact and thermal shock. The latter has importance in laser shock loading of structures.

7. Kinematics: This is a study of the geometry of motion and the optimum design of devices to perform various functions such as demanded by robotics for precise control and for operation under hazardous conditions. Examples of prime interest to the Army are recoil mechanisms, rapid and reliable ammunition loading devices, improvement of helicopter gear boxes and methods of power transmission. Research topics in this sub-field would include, for example, nonlinear dynamics of systems, non-Newtonian fluids, optimal mechanisms, gear tooth design, and mechanical or fluid power transmission concepts.

8. Experimental Methods: These include such techniques as photoelasticity and photoplasticity, strain gage devices, holography, acoustic emission, exo-electrons, and Fourier transform infrared spectroscopy. The purpose is to measure stresses, strains, and displacements; to detect the formation of cracks and the incipience of failure; to measure wave velocities and vibration frequencies; and to determine all material parameters necessary for quantitative determination of material response and to assist in design.

Included in these sub-categories are four specific research areas which need special attention: wear and erosion, kinematics and mechanisms, structural dynamics and impact and penetration.

In the future it is anticipated that more basic knowledge in wave propagation, particularly three-dimensional large amplitude motion, will be required in such areas as fuze design and shock loading. There will also be sought devices for crack detection in situ in metals and polymers in order that safety measures be taken in helicopter and weapon structures. Also, emphasis is to be placed on fretting corrosion, stress corrosion, laser hardening, stochastic processes and non-linear phenomena.

III. Fluid Mechanics (Dr. Robert Singleton)

Research in fluid mechanics is oriented toward the development of improved or new technology for those Army weapons or weapon components which involve the motion of gases and liquids. Included in this research program are both theoretical and experimental investigations on problems directly related to external flows past projectiles, missiles and V/STOL aircraft, particularly rotorcraft, and to internal flows such as occur in fluidic devices, gun barrels, laser cavities and small gas turbine engines. Requirements for fundamental studies are focussed into four main areas described below.

1. Rotorcraft Aerodynamics and Acoustics: Forces and moments produced on a rotorcraft both in hovering and forward flight regimes must be understood and predictable if increased performance, lower cost, greater reliability and increased safety are to be designed into the operational

configuration. Hence, the general problem areas of structure of turbulence in boundary layers, unsteady turbulent boundary layers, three-dimensional separation flow patterns, unsteady transonic flow, wind tunnel testing concepts, separated flows, vortex dynamics, and rotor systems and wakes, for example, are of great interest. In addition, noise produced by helicopters impairs tactical operations by both alerting enemy observers to the near presence of air mobile units and by causing pilot distraction and fatigue. Impulsive noise is of greatest concern but both discrete frequency and broadband noise are important. Of more recent interest due to nap-of-the-earth operational requirements are the absorption and reflection of sound from various types and shapes of ground terrain. A strong research program needs to be continued in this problem area, particularly on non-linear effects to insure substantial helicopter noise reduction in the next decade.

2. Ballistics of Gun Launched Projectiles: Problems related to the launching of a projectile from a barrel or tube and the projectile's flight along a trajectory to the target are the subject of this research area. The heat transfer to the barrel lining generated by the expanding gases, muzzle and open breech blast phenomena, the aerodynamic forces and moments experienced by the projectile during its flight, and internal motions of liquid-filled munitions are all of great interest. The understanding of these phenomena is essential to designing and producing artillery munitions with longer range and greater accuracy than presently available. Accomplishing these objectives requires investigations, for example, in the general areas of transition and turbulent boundary layers on spinning bodies; unsteady, turbulent, reacting flows inside gun tubes; multi-shocked flow fields; hypersonic flows at sea level conditions; transonic flows; base drag reduction; shell stability; and unsteady inviscid aerodynamics.

3. Missile/Rocket Aerodynamics: The control of guided missiles and the accuracy of missiles and rockets require a thorough knowledge of the forces and moments acting on them during both launch and free flight. Thus, the maneuverability and stability of missiles depend on the degree of understanding of such aerodynamic effects as missile component interference, aft-body plume interactions, vorticity shedding at high angle-of-attack, non-uniform onset flows and launcher-missile interactions during the initial phase of the flight, to mention just a few. Consequently, in order to improve and develop new high performance missiles for either anti-tank or air defense roles, it is necessary to maintain a vigorous program in this research area.

4. Bounded Flows: The motions of fluids within a region bounded by solid or porous walls are of particular concern in applications to radial and axial compressors and turbines, laminar proportional fluidic amplifiers and chemical laser cavities. The first type of flow problem requires investigations on strongly three-dimensional flows in ducts, secondary flow patterns, compressor-diffuser interfaces, heat transfer mechanisms and unsteady effects in variable-geometry machines. The second

example of internal flows requires studies on laminar flows in partially filled channels, effects of geometry and determination of stability mechanisms. The third case is concerned with turbulent mixing at low pressures, interfaces with diffusers, and effects of multinozzle arrangements, to mention a few. In general, this research area on bounded flows has not received its deserved attention; it is anticipated that more support will be given to those aerodynamic research areas that relate to flow field characteristics of small gas turbine engines. This particular research area is considered to be a candidate for a comprehensive multidisciplinary project and would most likely require a rather substantial investment in laboratory equipment.

Though all of these areas of fluid mechanics will receive support in the near future, it is expected that the first three areas will continue to be of higher priority than the latter one. In addition, research thrusts are planned on the specific subjects of flow fields exhibiting separation and stalling characteristics, the structure of rotor wakes and their interactions with adjacent surfaces, and the aerodynamics of radial and axial compressors including unsteady phenomena.

IV. Power Generation (Mr. James J. Murray)

Research in this area is undertaken in support of the following Army needs for improved and new technology: better air and ground vehicle power plants and the conservation of fuels, energy transfer efficiency, more efficient base power plants and auxiliary power units, better propellants for projectiles and rockets, and advanced-design power sources for high energy devices. Included in this program are both theoretical and experimental studies on problems directly related to the power plants or sources required.

A superior basic understanding of the technical behavior of power plants, propellants and fuels under various conditions in which the modern Army must operate is of considerable importance to achieve needed performance in terms of agility, firepower, durability, conservation of materials and fuels and reduction of logistic supplies needed for effective operations. Consequently, research is necessary in energy conversion, thermodynamics, heat transfer, structures, materials, fluid mechanics, fuels and energetic materials.

The sub-categories in power generation are discussed below:

1. Engine and Fuel Conservation: Vehicle engines and fuels must be better understood for improved performance, reliability, safety, maintenance, and fuel efficiency of Army ground vehicle and aircraft propulsion systems as well as mobile and stationary power generating plants. This program requires fundamental studies in engine combustion, heat transfer, thermodynamics, materials, fluid dynamics and chemical reactions to achieve a basic understanding of the phenomena occurring in internal combustion engines using various fuels.

Scarcity of domestic fuel reserves, potential vulnerability of foreign fuel resources and ever-increasing fuel costs require that the efficiency of fuel combustion processes be decidedly improved. Particular emphasis is placed on the diesel, turbine and standard carburetor-type engines; however, new and innovative engine concepts including multi-fuel capabilities should also be examined. Studies in this area should examine the in-chamber performance of an engine, the combustion chamber geometry, the wall, piston and upper chamber materials, fuel injection characteristics, flame propagation, chemical reactions and products, and the fluid mechanics and dynamics of the flow processes. This research area is a candidate for a comprehensive and multidisciplinary study involving both theoretical and experimental aspects.

Also of importance is the investigation of new and efficient processes for minimizing the complexity of refining crudes for use in military vehicles. This may be achieved by intensive research into the chemical and physical properties of available in situ crudes and by determining the interaction of these crudes with additives or various treatments for "on the spot" operation of Army vehicles in a combat area.

2. Propellants: The Army requires continuing and progressive research in the broad field of liquid and solid type propellants, both for launching and propulsion of missiles, rockets, and projectiles. Insofar as propellants are concerned, it is necessary to predict the ignition, burning, temperature and other rate effects such as pressure and volume changes, in order to obtain optimal conditions in the gun-missile systems. These needs call for basic understanding of all the involved phenomena of heat and mass transfer, thermodynamics, materials, chemical kinetics, fluid mechanics and shock and vibration.

GEOSCIENCES

I. Introduction

The Army's need for Geosciences research stems from the impact that the environment has upon strategy, reconnaissance, target acquisition, fire power, air and ground mobility, equipment, logistics and survival. Particularly desirous are research proposals oriented in the context of the "realistic battlefield environment" (arctic, desert, tropical and midlatitude); including (1) adverse weather conditions (fog, rain, snow, high and low temperatures, wind, turbulence, severe storms, etc.), (2) aerosols and gases from screening smokes, dust, combustion products (burning hulks, explosives), and (3) adverse terrain conditions (mud, sand, irregular land surfaces, flooded streams, frozen and snow-covered ground, varied vegetation, etc.). Conditions from approximately 1 km below the surface of the earth to 100 km above the surface of the earth are of interest.

The program spans an interest from innovative, perhaps high-risk fundamental research to more applied research which, nevertheless, has possibilities for broad application. The atmospheric sciences and terrestrial sciences are by nature interdisciplinary, and there is an increasing need for interdisciplinary teams to attack the complex atmospheric and terrestrial research problems. For more specific information on the program of the Geosciences Division, contact Dr. Leo Alpert (atmospheric sciences) or Dr. Steven J. Mock (terrestrial sciences).

II. Terrestrial Sciences

The terrestrial sciences program addresses those areas in which the Army must deal with problems arising from the terrain. This is admittedly an extremely broad and diverse subject area ranging as it does from seismic propagation in soils to techniques for automated mapping. Three major research categories or thrust areas are delineated with examples of major problems.

1. Properties of Earth Materials.

a. Soil and rock mechanics and dynamics (including snow and ice): This is an area of extreme importance to all phases of military construction from expedient field fortification to permanent facilities. Of particular interest are:

(1) Constitutive relationships under static and dynamic loading including two and three phase systems.
(2) Methods for testing and measuring properties in-situ.
(3) Relationships between laboratory measured properties and those in-situ.
(4) Stress wave propagation in unconsolidated, anisotropic media.

b. Soil Chemistry:

The basic chemical properties of clays and clay shales are of fundamental importance. Such studies can lead to improved methods for stabilization of roads and embankments, reduction of swelling in clays and prediction of compositional changes of diffusing liquids or gases through soils.

c. Novel techniques and instrumentation:

Remote (non-contact) and emplanted sensors or systems which can measure properties in-situ are highly desirable. Particularly of interest are methods for determining the complex dielectric constant as a function of depth in the near surface (down to 100 meters), systems to detect small scale anomalies, such as tunnels or caverns, and systems for measurement of seismic and electromagnetic anisotropy.

2. Earth-Fluid Dynamic Processes.

A continuous dynamic interaction between solid earth materials and the most abundant fluids, water and air, takes place. Military problems arising from these processes include localized severe flooding in battle areas, wave and tidal action on amphibious operations or port and harbor installations, natural or battlefield induced dust as a function of soil properties, and vehicle induced susceptibility to erosion of terrain.

Military hydrology in particular is a high priority area of needed research with two specific research goals within the terrestrial sciences:

a. Soil Moisture:

Questions remain as to whether the physics of time dependent water movement in soils having sporadic surface inputs is well enough understood to successfully develop adequate soil moisture predictive models. Research is desired in the following areas:

(1) Experimental and theoretical studies of time dependent vertical movement of moisture with variable inputs.
(2) Modeling efforts to predict soil moisture profiles. These may be stochastic, deterministic or some combination of the two.
(3) Methods to measure/monitor soil moisture (1) by remote means, (2) with emplanted sensors or (3) combinations of these.
(4) Spatial variation in soil moisture as a function of terrain, soil types and microclimate.

b. Rainfall-Runoff Modeling:

Streamflow modeling has reached an advanced state in civilian use for flood forecasting and routing. The military addresses a more difficult problem, namely forecasting runoff in small to medium sized ungaged basins. Specific research areas are:

(1) Parameterization of stage frequency as a function of basin characteristic and antecedent conditions.
(2) Remote sensing of stream state, i.e., width, depth and velocity.
(3) Adaptive hydrologic models for sparse data areas, i.e., which of the available hydrologic models are best used in areas having variable topography, vegetation and amounts of data.

3. Remote Sensing and Mapping.

The Army continues to increase the use of remote sensors to provide information on atmospheric conditions, for intelligence purposes, for mapping and a variety of other uses. Areas of research interest in the terrestrial sciences include:

a. Novel concepts and techniques for measuring and interpreting surface and subsurface properties and anomalies.

b. Theoretical and experimental studies leading to terrain modeling, sensor modeling and feature signatures in frequencies from microwave to ultraviolet in relation to feature extraction, reference scene generation and simulation.

c. Image (and other) sensor interpretation and processing research directed toward automation of the mapping processes from image acquisition to data base preparation, map and other terrain display products.

III. Atmospheric Sciences

The atmospheric sciences program is subdivided into five major reresearch categories: (1) Cloud and Aerosol Physics, (2) Atmospheric Effects on Transmission, (3) Small Scale Atmospheric Processes, (4) Middle Atmospheric Processes, and (5) Atmospheric Sensing and Probing.

1. Cloud and Aerosol Physics.

The Army has a requirement for basic understanding of the atmosphere as an aerosol system and the involvement of particulate matter in meteorological processes. Furthermore, the Army must recognize that in the battlefield, the majority of aerosols present may be a direct result of military activity, i.e., smokes, dust, etc. which interact with the local weather and affect military systems in various ways. Specific areas of priority interest requiring basic research include:

a. New concepts for determining, analyzing and characterizing the natural and manmade solid and liquid particles in the atmosphere including the origin, size, concentration, shape, orientation, composition, source and sinks, frequency of occurrence, temporal and spatial variations, interactions, changes with time, deposition and scavenging.

b. Physical, chemical and electrical processes and meteorological conditions resulting in the formation, growth and dissipation of natural aerosols (cloud, fog, precipitation) and artificial aerosols (smoke, battlefield-induced dirt, dust, etc.), and theoretical models of these processes.

c. Application of specialized laboratory and field measurement system, i.e., spectrophones to measure absorption of "dry" particulates, fog and smoke.

d. Improved methods for characterizing the battlefield environment through measurement of characteristics and obscuration effects of battlefield smokes and dust under varying meteorological conditions.

2. Atmospheric Effects on Transmission.

Active and passive electro-optical sensor and guidance systems operating in the millimeter through ultraviolet region are performance-limited by the atmosphere. Major impacts are beam wander, beam spread and scintillation due to optical turbulence; absorption by gases; scattering and absorption by aerosols; and ventilation of the heated air contained within the high energy laser beam propagation path, and other effects due to crosswind. Laboratory and field measurements of transmission properties (particularly in the millimeter and submillimeter region) are needed to assist systems designers, modelers and users. Specific areas of basic research interest include:

a. Measurement of absorption coefficients of gases, line shapes, self- and foreign-broadening coefficients, and temperature dependencies of battlefield and induced gases. Sensitivity studies are needed to determine effects on Army infrared and near-millimeter-wave systems.

b. Optical effects of aerosols (natural, smokes and dusts) including absorption, scattering, refractive index, shape and size distribution.

c. Better understanding of optical turbulence, in-situ and path integrated measurements for different atmospheric conditions, locations and time of day.

d. Effects of "low visibility" conditions (fog, clouds, precipitation, dust and smoke) on propagation characteristics.

e. Numerical and empirical techniques and models describing the effects of meteorological elements on atmospheric transmission from the ultraviolet to centimeter wavelengths.

3. Small Scale Atmospheric Processes.

Knowledge of the dynamics, physical and chemical phenomena of the lower atmosphere (0-10 km altitude over the battlefield) is important for many Army activities relating to chemical, biological and nuclear defense, air and ground mobility, construction, logistics, fire power, reconnaisance, target acquisition, and others. The primary interest is in the development of numerical and empirical techniques and models to quantify meteorological conditions on the mesoscale for analysis, depiction and prediction of meteorological conditions over the battlefield with a typically limited amount of data. Specific areas of basic research include:

a. Three-dimensional numerical models for predicting mesoscale flow including effects of topography, diabatic heating, internal boundary friction effects, etc.

b. Development of advanced models of atmospheric time and space variability in the time regime of two hours and space regime of 40 km horizontal and 5 km vertical.

c. Models capable of predicting transport, diffusion and interaction of natural and manmade materials released into the atmosphere in complex terrains and/or under adverse weather conditions.

d. Theoretical models of clouds (convective and stratiform) including physics and triggering mechanisms.

e. Simulation models for estimating turbulent exchange between various surfaces and the atmosphere.

4. Middle Atmospheric Processes.

Knowledge of the dynamics and chemical and physical phenomena of the atmosphere in the altitude range of 10 - 100 kilometers enables the Army to fulfill its responsibilities for ballistic missile defense, quantifying nuclear weapons effects, and strategic and tactical communications functions at all times and under all atmospheric conditions. The need is to conduct aeronomic studies which will assist in the understanding and prediction of the normal and nuclearly perturbed atmospheric environment. This information will assist in the assessment of atmospheric effects on Army systems or concepts, in the construction and validation of atmospheric environments and effects models, and in the development of mitigative or circumventive techniques. Appropriate areas for basic research include measurement, analysis, modeling, and simulation of:

a. The diurnal, seasonal, latitudinal and altitudinal concentrations of atmospheric constituents including electrons, negative ions, neutral species, and molecular conglomerates.

b. Atmospheric dynamics including diffusion, winds, waves, heave, and striations.

c. Radiation producing ionization, excitation, and dissociation in conjunction with measurements of atmospheric species concentration.

d. Atmospheric electricity including ionic mobilities, conductivities, electric fields, and collision frequencies.

e. Atmospheric temperature, density, and pressures in conjunction with the above measurements.

5. Atmospheric Sensing and Probing.

Recent advances in remote and in-situ atmospheric sensing and probing technology using satellite-borne sensors, microwave radar, laser radar, passive radiometry and acoustic sounding, have demonstrated the feasibility of real time and continuous surveillance of specific atmospheric parameters. In addition, there are indications that this can be accomplished economically, and with spatial and temporal resolution and precision not attainable with traditional techniques. Further development of these techniques applicable to problems in the preceeding four thrust areas is needed.

a. Techniques for remotely measuring the optical properties of the atmosphere including natural and manmade aerosols.

b. Techniques for automated, remote measurement of standard meteorological parameters, i.e., precipitation, temperature, humidity, cloud height, horizontal and slant range visibility, pressure, turbulence, wind, crosswind, windshear and others.

c. Techniques for utilization of the unique observational capabilities of meteorological satellite viewing and sounding capabilities for mesoscale applications.

d. Techniques to provide meteorological measurements from remotely piloted vehicles.

V. Concluding Remarks

It has been noted that in many cases geoscience research is best addressed by interdisciplinary teams. Submission of research proposals from such team efforts is encouraged.

The listed research problems are not exhaustive, but are meant to serve as a guide to identify major problem areas. We recognize that imaginative research often cannot be directly related to present Army needs. Thus, we invite further inquiries in areas not directly addressed above.

MATHEMATICS

I. Introduction

Mathematical techniques pervade research, development, testing and evaluation problems encountered by the Army. Furthermore, increasing demands are being placed on research in mathematics because of its fundamental role in the analysis and modeling of problems arising in Army science, engineering and operations. To meet these increasing demands, the mathematics program of the Army Research Office attempts to systematically advance fundamental knowledge in mathematics that will meet future and present Army needs. To accomplish these objectives, the program supports an extramural basic research program by highly qualified investigators in many areas of applicable mathematics. Based upon the present and projected needs of the Army, the research program in mathematics is organized in four broad subareas:

Applied Analysis
Numerical Analysis and Mathematical Software
Statistics and Probability
Operations Research.

II. Program Description

In the following sections, specific program objectives are described in the four sub-areas mentioned above. Clearly, the program does not cover the total spectrum of mathematical research in any particular subfield. Rather, it attempts to concentrate on those topics which appear to have impact on relevant Army problems in some reasonable time frame. The emphasis of the program, therefore, is reflected through a judicious mixture of both short- and long-term goals. In the descriptions which follow, an attempt has been made to relate research areas to functional areas. Also, there will be unavoidable overlap between various sub-areas, but the differences in major thrusts are appreciable enough to require separate descriptions. Prospective investigators are encouraged to contact the person or persons listed with each sub-area.

A. Applied Analysis

Program Director: Dr. Jagdish Chandra

The research program seeks to provide a fundamental understanding of the qualitative features of the basic equations of classical applied mathematics. Specific motivation comes from such problems as heat transfer in weapons and other structures, elastic-plastic analysis of gun tubes, aerodynamics, chemical kinetics and combustion, guidance and control, and communications and systems. A significant portion of these problems leads to the study of ordinary or partial differential equations which are mainly nonlinear. Therefore, the major thrust in this sub-area is on the mathematical analysis of nonlinear systems. The research is concentrated on asymptotic analysis, stability and bifurcation studies, and stochastic modeling of dynamical systems.

B. Numerical Analysis and Mathematical Software

Program Director: Dr. Paul T. Boggs

Research in numerical analysis is devoted to the understanding and development of efficient and accurate numerical schemes and to the associated high quality mathematical software. Many Army problems give rise to mathematical models whose exact solutions cannot be analytically expressed and must, therefore, be approximately obtained. In other cases, exact solutions must be accurately and stably evaluated. Examples of the first class include many of the problems mentioned in the applied analysis area while examples of the second class stem from classical linear theory and statistics. The research thrusts in the numerical analysis and mathematical software area include the development and analysis of methods for partial differential equations - especially nonlinear and time dependent PDEs and those arising from special areas such as fluid mechanics, aerodynamics, and chemical kinetics. Complementary to this is the development of the underlying technologies in numerical linear algebra and nonlinear algebraic systems. A second thrust concerns numerical algorithms for data analysis and statistics with the emphasis on robust procedures and the application of modern numerical analysis to these areas. Finally, there is a thrust in mathematical software aimed at research necessary to efficiently implement certain algorithms, including the automatic detection of errors in software and the testing and evaluation of competing routines.

C. Statistics and Probability

Program Director: Dr. Robert L. Launer

The main goal of this program is the development of valid theory and useful techniques for proper interpretation of data. The Army is constantly involved in testing and evaluating equipment to assess performance characteristics and predict reliability of these items. A recurring problem in these evaluations is uncertainty about the underlying model along with small sample sizes which are usually caused by high testing costs. Such data sets are extremely difficult to analyze and draw inferences from. In many cases, equipment is tested under deliberately imposed overstressed conditions in order to reduce testing time. This leads to many unanswered theoretical questions and practical difficulties. Many Army problems in target tracking and identification lead to data sets with many variables and unidentified parameters. Data sets with multiple outliers are also common. The program, therefore, mainly consists of, but is not limited to, research in robust statistical methods, multivariate analysis and the theory of statistical life testing.

D. Operations Research

Program Directors: Dr. Paul T. Boggs and Dr. Robert L. Launer

The operations research program is motivated by problems related to logistics, combat modeling and optimization originating from engineering and scientific applications. The thrust of the program is the development and analysis of methods to effectively treat such problems. The current areas of emphasis in the operations research program are simulation with emphasis on validation and output analysis, and large scale optimization. There is also a small effort directly in the area of combat modeling. The program is closely coupled to the statistics program since much of the effort is stochastic in nature. It is equally coupled to the numerical analysis program since virtually all of the algorithms generated require the use of a computer.

III. Current Priorities

While the above descriptions reflect the current program, there are areas of higher priority among these. This of course does not mean that the Mathematics Division will exclude other proposals from consideration, but does reflect the Division's intentions to develop programs which take into account changing research trends as well as changing Army needs.

For FY 80, the high priority areas include nonlinear evolution equations and robust statistical procedures. Included in the former area are the actual modeling of complex, time-dependent, physical phenomena, the qualitative and numerical analysis of nonlinear differential and integral equations and the mathematical software associated with such equations. The latter will include the analytical investigation of robust procedures for treating various distributional anomalies as well as new numerical approaches for dealing with the complex iterative formalism inherent in such procedures. Efforts in these fields may tend to be large and sometimes interdisciplinary. The Mathematics Division will, therefore, consider to a very limited extent comprehensive (large) programs in such areas.

METALLURGY AND MATERIALS

I. Introduction

Materials provide mobility, firepower, communication and control, and personnel protection for the Army. Although metals continue to dominate ordnance, the demand for ever greater mobility and reliability of equipment continually increases the use of ceramic, polymeric, and composite solids for structural, electronic, and other functions wherein certain attributes (e.g., cost, refractoriness, corrosion resistance, strength-to-weight ratio, high temperature strength, resistance to wear and erosion) superior to those normally available in metals are required. During the next several years, more advanced materials, possessing unique properties (e.g., inorganic and organic materials exhibiting high electrical conductivity, new classes of polymers which exhibit both useful toughness and environmental stability at elevated temperature, and composites with high stiffness and strength/weight characteristics) will find more extensive service in the Army's helicopter components, weaponry, guidance packages, and other systems.

The development of new materials that meet the demanding requirements of the Army, and the tabulation of physical, mechanical, and chemical properties for use by designers, will be most successful if based upon an appropriately oriented program of research. Discovering the fundamental factors which govern reproducibility in processing and properties of these materials as well as their reliability in service has become a matter of urgent importance. The empirical method of development by trial and error is wasteful of time, effort, and resources. Hence, the fundamental aim of ARO's program of research on materials is to discover the relationships between the composition, structure, and useful properties of materials. The correlative aim is to master the principles whereby a desirable composition and structure may be dependably and repetitively produced. Only when research has provided adequate knowledge about the constitution of solid substances and about their response to the various ambients encountered in service can the scientific design of new materials with predictable properties become successful.

II. Primary Objectives and Approach

Primary Objectives

- To gain fundamental knowledge that will enable the synthesis and/or processing of high-performance materials more readily, at lower cost, and with reproducible properties;

- To provide information that will form the basis for design and selection of materials that are strong and tough, resistant to attack by chemical action, radiation, or other severe environmental phenomena;

- To determine the mechanisms and key materials variables that enhance or limit the transmission, storage, or conversion of magnetic, electrical, and other forms of energy;

- To evolve efficient and reliable tests, both destructive and nondestructive, that will ensure consistent performance and reliability of materials.

Approach

In order to accomplish these primary objectives, individual work units are organized into the following subfields:

A. Degradation and Reactivity
B. Mechanical Behavior
C. Synthesis and Processing
D. Effects of Structure, Defects, and Composition on Physical and Chemical Properties
E. New Concepts in Testing and Analysis

The program in degradation and reactivity of materials includes projects spanning the range from those of a more applied nature (studies in corrosion, oxidation, hot gas erosion, environmental effects on polymer based composites, and novel methods to protect materials from aggressive environments) to those which have a longer range outlook (fundamental properties of surfaces and interfaces, thermodynamic properties of materials, and kinetics of materials/environmental interactions). The trends in this sector of research include degradation of materials under action of combined hostile elements (e.g., temperature, pressure, and highly reactive chemicals), and the reactivity of novel metastable materials formed by new technologies (e.g., ion plating, laser processing of surfaces, materials produced by rapid solidification).

The program on mechanical behavior of materials addresses a wide range of materials and topics, for example, solid particle erosion, fracture and fatigue mechanisms of metals, ceramics, polymers, and composites, mechanisms of plastic deformation, creep of metals, polymers, and ceramics, failure under shock loading, micromechanisms of wear, fretting, adiabatic shear, fracture toughness. Trends in this sector of research include studies of strengthening and failure at higher rates of loading (such as shock and laser pulsing), more complex loading conditions, severe environments (higher temperature, aggressive chemical atmospheres) and in more complex materials (such as high-performance composites and advanced polymeric systems).

The program on synthesis and processing of materials includes such topics as refining by fractional melting, the relationships of processing parameters for polymers to their resultant morphologies and properties, molecular design of new polymers, ceramics and metals (including hybrid combinations of these three), and factors affecting microstructural evolution during sintering in the presence of a liquid phase. The desired results of this research are the discovery of the fundamental principles which relate the processing parameters to the final microstructures and properties of materials, the discovery of methods to assure reproducible fabrication of materials, and increased reliability of materials in long term service. Examples of trends in this program include new means of forming and consolidating non-equilibrium materials in bulk form, novel techniques for deposition of protective coatings, clarification of the mechanisms which control the joining of materials, and understanding the epitaxial regrowth which occurs during metalization of semiconductors.

The program on effects of structure, defects, and composition upon physical and chemical properties covers a wide range of topics, such as the relation between electronic structure and magnetic properties of alloys, structure and defects in solid electrolytes, high-pressure equation of state of metals, role of hydrogen in metal alloys and hydrides, effects of atomic and electronic structure on carrier transport in oxides and nitrides, structure and properties of amorphous materials. The trends in this sector of research include improved characterization of defects in electronic, magnetic and optical materials, understanding of the role of defects and composition of electronic materials as microstructural dimensions become smaller, structure-property relationships of amorphous materials, novel materials with unusual structures and properties (e.g., ion implanted materials, intercalation compounds).

The program on new concepts in testing, analysis, and simulation contains such topics as characterization of point and boundary defects with positron annihilation, laser photoacoustic techniques, vibrothermographic examination of composite materials, inelastic electron tunneling spectroscopic techniques for study of corrosion, simulation of phase equilibria structures and defect structures. The trends in this sector of research include discovery of novel analytical techniques for characterizing defect structures and methodology to predict the effects of defects, structure, and/or composition on behavior of materials without performing full scale property determinations.

III. Thrusts

Several areas are identified as thrusts owing to their importance to Army needs, their timeliness, and their potential for large payoff. One such thrust is the behavior of materials under high rates of energy impingement, e.g., ballistic shock and laser pulsing. Examples of research to be included in this thrust are absorption and dissipation of energy (mechanical, electromagnetic, and thermal) by materials, failure modes (fracture, spallation, melting, ablation, etc.) of materials under high loading rates, and the role of phase transformations, surface properties, and microstructure of materials in interactions with high energy sources.

The accelerating rate at which technology is placing increased demands on the performance of materials in a wide variety of applications indicates that some limits of performance of conventional materials will be reached at a point in the near future. This situation substantiates the need for new processing techniques and new materials which have properties or combinations of properties heretofore unavailable. For example, the requirements for higher computational rates has pushed the circuit density on integrated circuits (and subsequently reduced the microstructural dimensions) to astonishing levels, and it is clear that a practical limit in microstructural dimensions will be reached with currently available processing techniques, circuit designs and materials. A thrust on *tailored properties of materials through structural control* to provide knowledge on the fundamental relationships among materials synthesis, structure (electronic, morphological, and defect), and properties will form the basis for the discovery and development of novel materials to meet future demands. Examples of research topics to be included in this area are diffusion kinetics and annealing behavior of defects on the submicron scale, novel electrical, magnetic and optical materials (electrical insulators with high thermal conductivity, novel magnetic materials for high frequency circuits, etc.).

In addition to the need for novel materials having tailored properties, there is a closely allied, yet broader need to study the processing itself. While the materials and processing cannot be separated, there is a thrust with emphasis on *new methods of synthesis and processing* to provide means to increase the reliability and reproducibility while reducing the cost of new materials. The interest in this thrust is on discovery of novel processing techniques rather than incremental improvement of existing techniques. Examples of research included in this topic are techniques for producing materials having graded structures and compositions, techniques to reproducibly fabricate metastable microstructures (noncrystalline solids, supersaturated solid solutions, ultrafine microstructures), techniques to control the mechanical behavior and chemical reactivity of surfaces, novel techniques to join similar and dissimilar materials.

Research in the area of *textiles and fibers* will be expanded owing to advances in fibrous materials and methods of construction of fabrics to take advantage of their unique properties. Emphasis will be placed on areas such as the effects of chemicals on the degradation of fibers and fabrics, on surface conditions of fibers, fabric morphology, etc., and their influence on the response of these materials to high rates of loading, and on the tailoring of fibers and fabrics to perform more than one function in service (e.g., fibers which are mechanically strong and electrically conducting).

IV. Comprehensive Programs

Three topics with high priority at this time, and which are considered appropriate for comprehensive programs as mentioned in the Introduction, are: *tailored properties through structural control*, *behavior of materials under high rates of loading*, and *novel materials processing*.

The foregoing areas are not intended to reflect all of the activities of the Metallurgy and Materials Science Division. We have special interests in novel concepts and phenomena in materials science which may have downstream applications for the Army.

Points of Contact:

Dr. John Hurt - ceramics, composites; electrical, magnetic, optical properties; defects

Dr. Phillip Parrish - corrosion, gaseous reactions, electro-chemistry, phase transformations, solidification, thermodynamics, kinetics

Dr. George Mayer - deformation mechanisms, strength, fracture, materials processing, polymer structure and properties

These areas of responsibility overlap in some instances. For situations where the point of contact is not clearly defined, or for subjects not listed above, contact the Division Director, Dr. Mayer.

PHYSICS

I. Introduction

The objective of the Physics Division program is the discovery and exploitation of physical concepts, phenomena, experimental and theoretical techniques, and data that can be expected to improve Army technology, equipment, and practices.

In practice, funding constraints limit support to a relatively few task areas at any one time. Additionally, much of the support is for effort which is multidisciplinary or for effort which may involve a relatively small component of "physics". This is because the first priority is for military potential rather than the design of a program which is representative of contemporary physics research.

Nevertheless it is useful to discuss the current interests of the Physics Division in terms of the well defined subdisciplines of physics. The following guidelines should be treated as a very broad boundary on the future interests of the Division. In the final analysis the direction of the program is based on the creativity of the scientific community. New ideas are often generated which fall outside of any categorization scheme but which are of high military and/or scientific potential. Thus even in periods of tight budgets, program suggestions which address these criteria are always welcome.

II. Program areas of interest

1. General

ATOMIC & MOLECULAR PHYSICS: Energy and charge transfer, electronic excitation and relaxation of excited states. Spectroscopic investigations and techniques, fluorescence, radiationless transitions and optical pumping.

OPTICS AND LASERS: Optical information processing, image formation and analysis including optical storage and retrieval, communication, image restoration. Laser physics, devices and applications. Optical devices, techniques and applications. Electro-, magneto- and acousto-optic phenomena.

ELECTRICAL PHENOMENA IN GASES: Physics of electrical discharges and electromagnetic interactions with discharges.

CONDENSED MATTER: Determination of lattice defects in amorphous and crystalline materials, extreme thermophysical properties, lattice dynamics, phase transitions, transport properties, surfaces and interfaces, dielectric and optical properties, electron and ion emission, methods of crystal growth.

ELECTROMAGNETIC TECHNOLOGY: Energy conversion and storage; the physics of electron tubes, semiconductor devices, dielectric devices, photoelectric and optoelectronic devices and systems.

2. Specific Thrusts

NEAR-MILLIMETER WAVES: Particular emphasis will be given to the region of the electromagnetic spectrum near one millimeter, especially in the atmospheric windows. Efforts in this area will be involved mainly with spectroscopic investigation where the information obtained may lead to new source concepts. For example, studies may provide information on chemical composition, excitation parameters and energy dynamics of candidate materials for near-millimeter lasers. Impurity level transitions in semiconductors is an area which may provide new options for the generation of near-millimeter-wave radiation.

OPTICAL PROCESSING: Emphasis will be placed on the exploration of hybrid optical/digital processing, nonlinear processing techniques, linear space variant processing, optical multistability, and wavefront reconstruction using either conventional or integrated optical systems.

Optical materials and design: Development of holographic materials and materials with controllable index of refraction gradients are of interest. Methods of design and specification of optical systems using these new materials must be developed concurrently.

OPTICAL FILMS: An area of special interest is the electrical properties of optical films. It is well recognized that such films interact with the substrates. A deeper understanding of the properties of these films can be obtained by combining a theoretical program with an experimental program to permit testing of model calculations and to provide a possibility to extend the theories to other substrates.

UNSTABLE LATTICES: The theory of unstable lattices has been an area of special interest and as the experimental situation has grown one begins to see that many of the phenomena involve properties not correlated with the periodicity of the lattice. Charge density waves (CDW) are examples of systems which may or may not correlate with the lattice and contribute solutions to some of the puzzles which have been found in solid state phenomena. We have special interest in such systems both in classical materials where CDW are known to contribute to puzzling behavior (potassium) and also in some of the new polymers where CDW are thought to be important in the properties that have been reported.

III. Staff

There are five memebers of the Physics Division technical staff.

Their general areas of responsibility are:

- Dr. Robert Lontz, Director
- Dr. Charles Boghosian, experimental solid state
- Dr. Mikael Ciftan, theoretical physics
- Dr. Issai Lefkowitz, experimental solid state
- Dr. Bob D. Guenther, lasers, optics, optical processing.

These areas of responsibility are not sharply defined and any questions concerning the most appropriate individual may be referred to the Division Director.